# ELECTRIC LIGHTING SYSTEM
FOR
# NORWALK, WISCONSIN

BY

G. I. STADEKER

ARMOUR INSTITUTE OF TECHNOLOGY

1914

THE INSTALLATION

OF AN

ELECTRIC LIGHTING SYSTEM

IN THE

VILLAGE OF NORWALK, WIS.

A THESIS

presented by

Gilbert I. Stadeker

to the

President and Faculty

ARMOUR INSTITUTE OF TECHNOLOGY

FOR THE DEGREE OF

ELECTRICAL ENGINEER.

May 1st. Nineteen Hundred and Fourteen.



approved
E. H. Freeman
Professor of Electrical Engineering
H M Raymond
L. C. Monin.

# T A B L E  O F  C O N T E N T S.

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# T A B L E  O F  P L A T E S.

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THE INSTALLATION OF AN ELECTRIC LIGHTING SYSTEM,

IN THE VILLAGE OF NORWALK, WIS.

## INTRODUCTION.

The "era of special design" is fast becoming a matter of history, and, as apparatus and construction materials become standardized, it is no longer necessary for the construction engineer to himself design practically all the engineering details of the work which he has to perform - but instead he finds it his duty to gain a wide knowledge of the standard productions of the great manufacturing companies, and to choose from these, standard productions such as will best fulfill his specifications. The advantages gained inthis manner - are -

First - Reduction in first cost.

Second- Ability to secure repairs promptly.

Third - More efficient and better designed apparatus (due to the design of each dtail by specialists employed in the works of the manufacturers).

Fourth- Quicker delivery.

This thesis is presented as an example of this modern engineering, embodying the application of principles in design which have proven themselves - by past experience to be satisfactory and successful; and furthermore exemplifying the use of standard apparatus throughout a complete lighting plant in a small community.

## SECTION I.

## HISTORY.

The Village of Norwalk, located in the western part of Wisconsin near La Crosse, is a small community whose 525 inhabitants are chiefly retired farmers with their families. After considerable political agitation, the Village Board decided to call a special election to determine whether an Electric Light Plant should be installed. As the result of the ballot in May 1913, the Village Board was authorized to proceed in the purchase and construction of such a plant, to be so designed that 24 hours service would be available. The proper legal steps were authorized to provide for the issuance of bonds amounting to Seven Thousand Dollars to cover the initial cost of the engine, generator, storage battery, line material and power plant building including the erection and installation of all the apparatus necessary to place the plant in operating condition.

The writer was requested to draw up specifications in detail, which included practically the design of the entire plant. The Board ultimately purchased an equipment in accordance with these specifications, and the plant is in successful operation at the present time.

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## SECTION II.

### Size of the Generator.

The first problem which presents itself in the design of any power plant - is the determination of the Size of the Generator. This problem is solved first by detailed analysis of the amount of power which the plant will be called upon to furnish. The result thus obtained should then be checked against the results which have been obtained in past experience with similar installations. If the two differ - then there must be some peculiarity about the installation under investigation, and this peculiarity should be isolated and given special attention in order to ascertain whether or not proper weight is being given to its influence.

The size of the plant in the case at hand was estimated by making assumptions of the loads required by the different classes of service at the time of the peak load, as given in the following table.

TABLE 1.

ESTIMATION OF THE PEAK LOAD.

| Type of Building | Number | Estimated Av. Consumption at Time of Peak Load. | Total Estimate Consumption at Time of Peak Load |
|---|---|---|---|
| Residences, | 90 | 100 Watts | 9,000 |
| Business Places, | 25 | 150 " | 3,750 |
| Churches, | 3 | 1500 " | 4,500 |
| Schools, | 1 | 1500 " | 1,500 |
| 100 Watt Street Lights, | 4 | 100 " | 400 |
| 60 Watt Street Lights, | 22 | 60 " | 1,320 |
| | | Total Lighting Load: | 20,470 |
| Battery Load (Estimated) | | | 5,625 |
| | | Total: | 25,095 |

This estimate is very liberal. The assumption is made that every house in the village will be wired for electricity. This condition will not exist. A second assumption is made that at dinner time and through the early hours of the evening, each one of the ninety residences will be burning four twenty-five watt tungsten lamps. This community is composed of farmers - accustomed all their lives to kerosene lamp light and most of them will probably be satisfied with one light in the dinning room, one in the kitchen, one in the sitting room and one on the porch; which will all probably burn during the peak hour. Other lights in bedrooms, barns, etc., will burn at off-peak-hours. However - a few cases of extravagance in fixtures, etc., will rapidly bring up the average - so that it is good practice in estimating the load for lighting the residences in a village of this character to use this figure of 100 watts per residence.

The estimate of 150 watts central station capacity for business houses is very fair - when consideration is taken of the type of business establishment typical of the town. There are but few concerns in the town which are progressive enough to illuminate their stores in a modern manner. In these few stores, for estimating purposes, the figure of one watt per square foot may be used; while in most of the stores it is safe to figure that a light will probably be used in each window with additional lights spaced ten or fifteen feet apart down the center of the store.

Each church will present a separate problem, and an accurate estimate of the load which they will supply can only be made after detailed study of each has been made. However, the figure of 1500 watts for each church is close enough for determing the central

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Each church will present a separate problem, and an accurate estimate of the load which they will supply can only be made after detailed study of each has been made. However, the figure of 1500 watts for each church is close enough for determining the central

station capacity. This figure may also be used in estimating the school house load.

The street-lighting load can be definitely determined be studying the conditions in the town. Reference to Figure 1 will show the plat of the town together with the location of the street lights as indicated by the circles drawn in at the street intersections. The size of the units is a question of importance which must be decided early in the study of the conditions. Small towns, prior to the installation of the Electric Light Plant - are generally lighted by ascetelene, gasoline, oil and sometimes gas. As a rule, these systems get run down and are valueless, and very frequently it is the poor street illumination that call the attention to the necessity for electric light. Under these conditions street illumination, which would be considered abominable in a city, is welcomed as a great improvement in the Village. It is practically unnecessary to endeavor to brightly illuminate the streets. All that is desired is that there shall be sources of light at intervals not too far apart so that it will be possible to discern objects which come between the source of light and a person stationed midway between two lights. If enough light is thrown down the street to make it possible to see the curb-line at any point, then the end has been met, and usually a great improvement has been made over the old system. 60 watt, 100 watt and 150 watt tungsten lamps, spaced 250 to 300 feet apart, generally meet the conditions satisfactorily.

At Norwalk, it was decided that four 100 watt lamps with suitable reflectors should be placed in the business districts on the four most important corners, and twenty two - sixty watt lamps scattered through

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At Norwalk, it was decided that four 100 watt lamps with suitable reflectors should be placed in the business district on the four most important corners, and twenty two - sixty watt lamps scattered through

the residence district. Gasoline street lamps had been used in the past, but at the time that the electric lighting was installed, but few of these lamps were in commission. Center-span suspension of street lamps was decided upon, inasmuch as this construction results in more efficient illumination of both sides of the street, althoughit necessitates the additional expense of two poles per lamp (one for each side of the street) instead of but one pole with a bracket arm.

The estimated peak load as shown by the tabulations in Table 1 is approximately 20.5 K.W. Sufficient generator capacity must be added to make it possible to charge the battery during the peak period and as a preliminary figure a 25 ampere, 225 volt battery was assumed as the maximum which would be required. This was determined from the following tabulation, which shows the size batteries and generator used in several installations in small towns.

TABLE 2.
BATTERY INSTALLATIONS IN VILLAGES.

| Population | Volts | Watt Hour Capacity. | E.S.B.Co. Type Designation | Gen. Size K. W. |
|---|---|---|---|---|
| 330 | 110 | 13200 | E-7 | |
| 400 | 110 | 8250 | D-7 | |
| 625 | 110 | 17600 | E-9 | 25 |
| 630 | 110 | 13200 | E-7 | |
| 630 | 110/220 | 26400 | E-7 | 30 |
| 650 | 110 | 17600 | E-9 | 17 |
| 700 | 110/220 | 17600 | E-5 | 40 |
| 725 | 110/220 | 35200 | E-9 | 30 |
| 750 | 220 | 26400 | E-7 | 30 |
| 775 | 110 | 22000 | E-11 | |
| 900 | 220 | 26400 | E-7 | 20 |
| 900 | 110 | 22000 | E-11 | |
| 980 | 220 | 26400 | E-7 | |
| 1050 | 110/220 | 26400 | E-7 | 25 |
| 1075 | 110 | 22000 | E-11 | 50 |
| 1100 | 110 | 22000 | E-11 | |
| 1200 | 110 | 17600 | E-9 | 72.5 |
| 1300 | 110/220 | 44000 | E-11 | 51. |

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| 620 | 110/220 | 26400 | [illegible]-7 | 30 |
| 650 | 110 | 17600 | [illegible]-9 | 17 |
| 700 | 110/220 | 17600 | [illegible]-5 | 40 |
| 725 | 110/220 | 35200 | [illegible]-9 | 30 |
| 750 | 220 | 26400 | [illegible]-7 | 30 |
| 77[illegible] | 110 | [illegible]000 | [illegible]-11 | |
| 900 | 220 | 26400 | [illegible]-7 | [illegible] |
| 900 | 110 | 22000 | [illegible]-11 | |
| 980 | 220 | 26400 | [illegible]-7 | |
| 1050 | 110/220 | 26400 | [illegible]-7 | 25 |
| 1075 | 110 | 22000 | [illegible]-11 | 30 |
| 110[illegible] | 110 | 22000 | E-11 | |
| 1[illegible]00 | 110 | 17600 | [illegible] | 7.5 |
| 1[illegible]00 | 110/[illegible] | 14000 | [illegible]-11 | [illegible]. |

The total estimated load is therefore approximately 25 K.W. However, no allowance has been made in the above estimates for the possible use of electrical appliances, such as fans, sad irons, electric signs, etc. It is also very probable that a motion picture theatre will be opened in the town, which in itself would add a 5 K.W. load. It was the general opinion of the Village Board that a large enough plant should be installed to take care of the load for several years to come. Reference to the price book of oneof the largest manufacturers brought out the fact that a 25 K.W. 950 R.P.M. d.c. generator was built on the same frame as a 30 K.W. 1300 R.P.M. generator, and due to its higher speed, the latter was actually $20.00 cheaper than the smaller machine. Therefore a 30 K.W. 1300 R.P.M. unit was specified.

The very satisfactory operation and freedom from trouble of the standard generators built by the reputable manufacturers makes it unnecessary to consider the purchase of two units - such as a 15 K.W. and a 10 K.W. so that a reserve unit will be available. The plant will be run only from sunset until about 10 o'clock. Therefore there will be no long period of light load when a smaller machine could be used to economically handle this load. In case of breakdown, the storage battery would be large enough to handle the entire load for the evening, thus allowing practically 48 hours in which repairs could be made before any inconvenience would be suffered. A few spare armature coils can be carried in stock to meet an emergency. The limitation of $7000.00 in available funds also made it imperative to build the plant as economically as possible and at the same time have it consistent with good engineering practice. All these considerations cemented the opinion that but one unit of 30 K.W. capacity should be specified. Reference to Table No. 2

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The very satisfactory operation and freedom from trouble of the standard generators built by the reputable manufacturers makes it unnecessary to consider the purchase of two units - such as a 15 K.W. and a 10 K.W. so that a reserve unit will be available. The plant will be run only from sunset until about 10 o'clock. Therefore there will be no long period of light load when a smaller machine could be used to economically handle this load. In case of breakdown, the storage battery would be large enough to handle the entire load for the evening, thus allowing practically 4 hours in which repairs could be made before any inconvenience would be suffered. A few spare armature coils can be carried in stock to meet an emergency. The limitation of $7000.00 in available funds also made it imperative to build the plant as economically as possible and at the same time have it consistent with good engineering practice. All these considerations cemented the opinion that but one unit of 30 K.W. capacity should be specified. Reference to Table No. 2

shows that this estimate checks closely with the size units in operation in villages of approximately the same size.

Engine:

Due to the fact that an oil engine has practically no overload capacity it is necessary to drive the 30 K.W. generator with at least a 50 H.P. engine so that the maximum load which the generator could carry will not exceed the maximum output of the engine. No effort was made to draw hard and fast specifications covering the engine, it having been considered advisable to allow the engine manufacturers to use their judgement recommending the details of this part of the equipment. The engine and generator specifications weredrawn as follows:

GENERATOR. The direct current generator to be furnished under these specifications is to be rated as follows:

> 1 - 30 K.W. 125-250 Volt, 3-wire direct current generator with proper sized pulley, sliding base and rheostat, speed not to exceed 1300 R.P.M.

The generator is to be of the interpole type, and must be capably of operating successfully in conjunction with oil engine.

<u>Rating</u>: The generator shall be capable of operating continuously for 24 hours at its rated full load with the rise in temperature of the coils not exceeding 40 degrees centigrade above the surrounding atmosphere and of the commutator 45%. After carrying full load for 24 hours, the generator must be capable of carrying an overload of 25% for two hours without temperature rise of more than 55 degrees centigrade on the coils or 60 degrees on the commutator above a room atmosphere of 25 degrees centigrade. Temperatures are to be measured by a thermometer in accordance with the rules of the American Institute of Electrical Engineers.

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Compensator: This generator shall be wound for 125-250 volts, 3-wire preferably equipped with a single phase compensator, mounted on the end of the armatures, by means of which 25% of the rated full load may be carried in the neutral. Resulting difference in voltage between the two sides of the circuit shall not exceed 5-volts, or 2% of the voltage between the outside wires. Alternative bids on a 3-wire generator with balancer coils will be accepted.

ENGINE. The engine is to be 50 H.P. mounted on strong cast iron base of sufficient height to clear the fly wheel. Oil engine is to be used in conjunction with a direct current 30 K.W. 3 wire generator. The engine is to be of the throttling type, with all the necessary accessories and appurtenances, including storage tank of sufficient capacity for storage of one carload (tank line) of oil, including necessary double endless belt for driving the generator.

The manufacturer that supplies the engine shall erect same complete on foundation to be furnished by the Village of Norwalk, and will be held responsible to supply absolutely everything required for the successful operation of the engine.

If the engine contractor fails to supply the necessary accessories and appurtenances for the successful operation of this engine, which are not mentioned in these specifications, and place the engine in perfect operating condition, the Village of Norwalk hereby reserves the authority to purchase the necessary accessories or labor elsewhere and deduct the amount involed from the contract price of the engine contractor.

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ENGINE. The engine is to be 50 H.P. mounted on strong cast iron base of sufficient height to clear the fly wheel. Oil engine is to be used in conjunction with a direct current 20 K.W. 3 wire generator. The engine is to be of the throttling type, with all the necessary accessories and appurtenances, including storage tank of sufficient capacity for storage of one barrel (tank line) of oil. including necessary double endless belt for driving the generator.

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## SECTION III.

### The System of Distribution.

<u>Alternating Current System</u>:

Prior to the election at which it was decided to purchase an electric lighting plant, estimates had been received on an alternating current equipment. In fact, complete specifications had been drawn by consulting engineer, based upon the use of alternating current. The natural tendency in the development of the lighting plants for small towns is toward alternating current. The reasons are so evident that they require no discussion here. However, the prime requisite of a satisfactory electric lighting plant in a village, is 24 hours service, and in a small plant, this can only be secured with a direct current storage battery system. The day load is so light, that the wages of the additional attendent who would be required to run the a. c. plant during the day would hardly be paid by the income accrueing to it. Therefore there are only three conditions which can warrant the consideration of alternating current in a village in which the farthest point to which current must be transmitted is less than half a mile. These conditions are -

1st. - The probability of a cross-country alternating current transmission system entering the village at a future date.

2nd. - The probability that the growth of the village will be rapid.

3rd. - The probability that a motor load of considerable proportions may be developed.

Regarding the first mentioned condition, the topographical location of Norwalk precludes any possibility of a transmission line being built near it. The village is located in a valley in the midst of the highest hills in Southern Wisconsin. The C. & N. W. R. R. passes through

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tunnels in the hills on each side of the town in order to get into it. Sparta is the nearest town of any size, and it is 12 miles away with no towns of an appreciable size between the two. Therefore there are no enticing conditions which might induce a transmission system to give Norwalk the slightest consideration when laying out its lines.

In reference to the probable growth of the town in the future, there is every readon to believe that it will be very slow. The population has not increased more than 50 people in a decade. A few farmers - retiring from active life - sell their farms and move into the village to add it its population. There are no manufacturing plants to bring laborors into the village, so that ten years from now the population will probably not exceed 600. Therefore it is doubtful if there will ever be the necessity for transmission of current much more than half a mile. The town cannot grow to the north and east, due to the proximity of the hills. The power plant is located in the southern part of the town, and the village limits in this direction are less than a quarter mile from it. All tendency toward growth of the village will be southward, so that it can grow considerable in this direction before the farthest house is an appreciable distance from the plant.

Mention has already been made of the absence of industries. The motor load which might be developed is negligible. There is one brick yard in the town employing a couple of men, but that is all.

The above conditions all lead to the conclusion that alternating current should be given no consideration in planning the lighting plant for this town.

Direct Current System:

An analysis of the data given in Table No. 2 shows that

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An analysis of the data given in Table No. 2 shows that

in the 18 typical plants investigated ten used the 110 volt 2-wire system, five used the 110/220 volt three wire system and three the straight 220 volt system. The predominance of the 110 volt system is probably due to lack of general knowledge concerning the 110/220 volt system. It is surprising to note the frequency with which this system is given no consideration by village boards or even electrical contractors in the preparation of specifications for these small plants. It is the opinion of the writer that the 3-wire system should be invariably recommended for the lighting of village where d. c. is advisable. The straight 220 volt system has proven to be dangerous when used on lighting circuits and should never be given consideration except for power purposes. The use of the straight 110 volt system results in extra investment in copper which is practically useless. The copper alone in a plant such as that under consideration represents approximately 7% of the total investment.

To substantiate this point, complete calculations were made as tabulated in Table Nos. III and IV. Figure 2 shows the diagram of the three feeder circuits. The first column of Table No.III refers to the sections of the feeder circuits corresponding to the lettering on Figure No. 2.

In these calculations it was necessary to make the following assumptions.

| | | |
|---|---|---|
| Average size of lamp used, | - | 40 Watts |
| Maximum load of average block of 12 residences, | - | 1200 Watts. |

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Average size of lamp used. - 40 Watts

Maximum load of average block of 12 residences. - 1200 Watts.

## TABLE NO. 3

## COPPER CALCULATIONS.

| Section | Ampere 125 V. | Ampere 250 V. | Length of Circuit (Feet) | Allowable Drop 125 V. | Allowable Drop 250 V. | Size of Wire 125 V. | Size of Wire 250 V. |
|---|---|---|---|---|---|---|---|
| Circuit #1 | | | | | | | |
| O A | 54 | 27 | 600 | 10 | 20 | #1 | #7 |
| A B | 12 | 6 | 300 | 2 | 4 | #4 | #8 |
| A C | 24 | 12 | 300 | 2 | 4 | #1 | #7 |
| C E | 12 | 6 | 300 | 2 | 4 | #4 | #8 |
| C D | 12 | 6 | 300 | 2 | 4 | #4 | #8 |
| Circuit #2 | | | | | | | |
| Q G | 86 | 43 | 600 | 9 | 18 | 2/0 | #5 |
| G H | 22 | 11 | 500 | 4 | 8 | #2 | #8 |
| G I | 18 | 9 | 300 | 2 | 4 | #2 | #8 |
| G S | 46 | 23 | 300 | 3 | 6 | 1/0 | #6 |
| S J | 18 | 9 | 200 | 2 | 4 | #4 | #8 |
| S K | 18 | 9 | 300 | 2 | 4 | #2 | #8 |
| S T | 10 | 5 | 800 | 2 | 4 | 1/0 | #6 |
| T L | 5 | 2.5 | 200 | 2 | 4 | #8 | #8 |
| T M | 5 | 2.5 | 300 | 2 | 4 | #8 | #8 |
| Circuit #3 | | | | | | | |
| O I | 86 | 43 | 300 | 5 | 10 | 2/0 | #5 |
| I K | 12 | 6 | 300 | 4 | 8 | #6 | #8 |
| K Q | 6 | 3 | 300 | 2 | 4 | #6 | #8 |
| I N | 72 | 36 | 300 | 4 | 8 | 2/0 | #5 |
| N R | 36 | 18 | 450 | 4 | 8 | 1/0 | #6 |
| N P | 18 | 9 | 450 | 2 | 4 | 1/0 | #6 |
| N U | 36 | 18 | 900 | 5 | 10 | 2/0 | #5 |

## TABLE NO. 4

## COMPARISON OF COST OF TRANSMISSION WIRE

## BETWEEN 125 VOLT TWO WIRE AND 125/250 VOLT THREE WIRE SYSTEMS.

T.B.W.P. WIRE $17.80 BASE.

125 VOLT SYSTEM.

| Feet of Wire. | Size of Wire. | Weight M Ft. | Cost |
|---|---|---|---|
| 4200 | #2/0 | 502# | $375.20 |
| 4000 | 1/0 | 407 | 289.98 |
| 1800 | 1 | 316 | 100.04 |
| 2200 | 2 | 260 | 101.53 |
| 2200 | 4 | 164 | 64.26 |
| 1200 | 6 | 112 | 23.92 |
| 1000 | 8 | 75 | 13.29 |
| | | Total: | $968.22 |

125/250 VOLT SYSTEM.

| Feet of Wire. | Size of Wire. | Weight M Ft. | Cost |
|---|---|---|---|
| 6300 | #5 | 134# | $150.27 |
| 8700 | 6 | 112 | 183.14 |
| 9600 | 8 | 75 | 120.17 |
| | | Total: | $453.58 |

The results show that the cost of distribution copper for the 125 volt system is $968.22 as compared with $453.58 for the three wire system.

The other factors, entering into the cost of the complete plant, which would be affected by the system of distribution, are tabulated below in Table No. 5.

TABLE NO. 5

COMPARISON OF COST OF

125 VOLT AND 125/250 VOLT INSTALLATION.

| Item | ESTIMATED COST 125 Volt | 125/250 Volt |
|---|---|---|
| Generator, | $350.00 | $419.00 |
| Switchboard, | 375.00 | 403.00 |
| Wire, | 968.22 | 453.28 |
| Insulators, | 35.40 | 23.60 |
| Total: | $1,728.62 | $1,298.88 |

The above tabulation shows a saving of $429.74 which could be effected by the use of the three wire system. The additional labor required to install the third wire has not been included in the above estimates, for this item at best is pure conjecture. The probabilities are that the comparitive ease of handling #5, 6 and 8 wire instead of the 1/0 and 2/0 wire (necessitated in large quantities by the 100 volt system) would nearly equalize the labor requirement of the two systems.

125/250 VOLT SYSTEM.

| Feet of Wire. | Size of Wire. | Weight M Ft. | Cost |
|---|---|---|---|
| 6300 | #5 | 154½ | $150.27 |
| 8700 | 6 | 112 | 183.14 |
| 9600 | 8 | 75 | 120.17 |
| | | Total: | $453.58 |

The results show that the cost of distribution copper for the 125 volt system is $968.22 as compared with $453.58 for the three wire system.

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| Wire. | 968.22 | 453.58 |
| Insulators. | 35.40 | 23.50 |
| Total: | $1,728.62 | $1,298.88 |

The above tabulation shows a saving of $429.74 which could be effected by the use of the three wire system. The additional labor required to install the third wire has not been included in the above estimates, for this item at best is pure conjecture. The probabilities are that the comparitive ease of handling #5, 6 and 8 wire instead of the 1/0 and 2/0 wire (necessitated in large quantities by the 100 volt system) would nearly equalize the labor requirement of the two systems.

In addition to its advantages from the monetary standpoint, the three wire system will be far better adapted to power installations should there be any opportunity for such at a future date.

In view of the above considerations, the definite decision was reached to install the 125/250 volt three wire direct current system in the Village of Norwalk.

## SECTION IV.

### The Storage Battery.

The size of the storage battery in any installation is a subject that allows for extended discussion. As a matter of fact, in a small village it is generally determined not entirely by the conditions, but to a large extent by the amount of money which there is available to be spent. If a large battery is bought, it need only be charged occasionally. It a small battery is bought, it will do the service just as well, but must be completely charged more frequently - resulting in shorter life. The large battery cost more money, but requires less attention. Therefore the battery size is very often dependent upon the inclinations of the purchaser toward convenience in the operation of his plant. From the engineering standpoint, this viewpoint seems entirely out of place, yet from the practical standpoint, it is the condition met every day. Taking the engineering view it is also met in the question which must first be answered before any steps can be taken in determining the battery size - i.e. "How frequently will the battery be charged?"

The standard practice is village lighting plants is to run the generator from darkness untul ten or eleven o'clock at night - shutting down whenever the load has fallen off to it's normal midnight value. The storage battery is then relied upon to carry the load until the street lights are extinguished and also to carry any daylight load which may be developed. It is therefore convenient to charge the battery every evening. In the winter, when the battery is called upon to do its heaviest duty, the sun sets early in the afternoon and the generator is started up early, thus making it possible to charge the battery for a

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The standard practice in village lighting plants is to run the generator from darkness until ten or eleven o'clock at night - shutting down whenever the load has fallen off to it's normal midnight value. The storage battery is then relied upon to carry the load until the street lights are extinguished and also to carry any daylight load which may be developed. It is therefore convenient to charge the battery every evening. In the winter, when the battery is called upon to do its heaviest duty, the sun sets early in the afternoon and the generator is started up early, thus making it possible to charge the battery for a

longer period of time each day than possible or required in the summer. This system of charging the battery every day, pumping back into it the equivalent of the energy which it delivered the night before, is conducive of the most satisfactory battery operation and long life of the plates, provided that an overcharge be given about once every week or ten days and the battery is never over-discharged. Thus the absolute minimum size of battery for a village plant must be that which will just carry the street lights and a small house lighting load from 10 P.M. until 7 A.M. Such a battery however, would undoubtedly be overworked and would wear out rapidly. Therefore a larger battery than this should be installed, and it should be of such size that it can be relied upon for reserve service in case of breakdown of the generator. In other words, it must be large enough to carry the street lights from 5 P.M. until 7 A.M. and in addition carry a portion of the residence and store lighting. Thus, thirty six hours would elapse after the breakdown of the generator before the town would be in total darkness, and the battery, in addition to serving it's normal function of lighting the town, would also serve as a source of protection against complete breakdown. Just how far this protection is to be carried generally is determined by financial conditions at the time that the plant is being purchased. If considerable funds are at hand, a generous battery can be purchased, but if under other conditions, it is recommended that the battery be at least large enough to carry the street lights for fourteen hours.

Preparations for future growth of the battery load should always be made by installing the plates in jars large enough

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Preparation for future growth of the battery load should always be made by installing the plates in jars large enough

to accomodate four additional plates. For instance, an E-7 Chloride Accumulator Battery, consisting of seven size E plates, should be installed in E-11 jars, which will accomodate eleven size E plates. At a future date the four additional plates may be added and the capacity of the plant increased by 80 ampere-hours at a minimum expense.

The street lights in Norwalk aggregate 1720 watts, and would require a battery having a capacity of 24080 watt-hours to carry this load for 14 hours. Batteries of approximately the size which would be required in this installation are rated at 10, 15 and 20 amperes at 220 volts for 8 hours, equivalent to 16600, 26400 and 33200 watt - hours respectively. The comparative costs of these batteries, based upon prices which would be quoted under conditions of normal competition are $1336.00 $1722.00 and $2312.00. Undoubtedly the 10 ampere battery would give satisfactory service, inasmuch as it would be large enough to carry the street lights for nine hours, yet in case of breakdown of the generator it would but partially tide the plant through the night. For an additional $386.00 in a total expenditure of $7000.00 a 15 ampere, 26400 watt battery can be purchased which would carry the street lights 14.5 hours. The 20 ampere plant is larger than is actually required. This latter size was actually called for in the advertisement for bids, but alternatives were offered on the 15 ampere plant, with the recommendation that this size be purchased with jars large enough to allow for the increase of the battery capacity to 25 amperes by the addition of four more plates.

The method of charging the battery here enters into consideration. Approximately 300 volts are required to completely charge a 220 volts battery. Standard generators are rated at 250 volts; 300 volt

apparatus is special and therefore high in price. Furthermore, a loss of energy occurs during charging periods when it is necessary to insert resistance in the main feeder circuits to cut the line voltage down to 220 volts. A booster set can be installed in plants large enough to warrant their use, but by far the simplest arrangement is to charge the battery with two halves, each 110 volts, in multiple, connected across the 220 volt mains with a suitable charging resistance in the circuit to cut the voltage down to the proper valve of approximately 150 volts. On discharge, the two halves are connected in series, with countercells to provide for adjustment of the line voltage.

With this arrangement the battery can float on the line if desired, and when the generator is shut down regulation of the line voltage can be obtained by manipulation of the countercell switch.

This system represents the nearest approach to standardization in battery control of which the writer is aware. Almost every battery installation has its own peculiarities,yet, while the multiple charging scheme has its drawbacks, it is the best scheme which has as yet been presented for standard small lighting plants. Figure No. 3 is a schematic diagram of this arrangement.

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## SECTION V.

### The Switchboard.

In the introduction to this thesis, mention is made of the fact that this work is written as an exposition of the present day trend toward the use of standardequipment in small power plants. This trend is nowhere so apparent as in switchboard design. Standard generator and feeder panels to meet all normal conditions have been designed and catalogued by the large electrical manufacturers. Wiring diagrams, are all drawn, templets for drilling the slate made, and specifications for materials used in the construction of these "standard panels" are all ready to be sent to the storekeeper on a moment's notice. Thus the prices of standard panels are very low, and the sales engineer finds it his duty to apply these panels to the purchaser's conditions. This is of benefit to both the buyer and seller. It makes it possible to quickly determine which of several prospective layouts will be the cheapest; for reference to the catalogue will quickly determine the comparitive prices. All that the customer demands is a board which will satisfactorily do his work, at the lowest possible cost. Thus the conditions which surround the installation must first be thoroughly studied. Then reference to the catalogue determines to a large extent the layout of the panels.

In the plant under consideration, the question as to whether or not a circuit-breaker should be used in place of fuses to protect the generator is settled by the Board of Fire Underwritters, who specify a double pole breaker in the main line. Likewise a ground-detector device

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is required. For intelligent operation of the plant, an ammeter must be placed in each of the two outside generator mains.

The voltmeter can be mounted on the panel, for the switchboard is short and a swinging bracket means added expense. The potential receptacle and the ground detector receptacle should both be mounted on this generator panel together with the rheostat.

There are three feeder circuits required by the system of wiring the town as shown in Figure No. 2 each of which require a feeder switch.

Four street lighting circuits were arranged for, one for the heart of the town, and one to feed the section of the town to the north, one to the east and one to the south-west. The south eastern section of the town is simply farm lands and requires no lighting.

The battery panel requires a single pole circuit-breaker with a reverse current relay as a protection for the battery in case the generator voltage falls below the battery voltage; so that the battery will not become short circuited by the generator in case the battery slows down or stops unexpectedly. While the battery is being charged with two halves connected in multiple (as explained in the discussion of the battery in Section IV) an ammeter is required in each half to read the charging current. A voltmeter receptacle connected to the voltmeter on the generator panel serves to indicate the voltage of each half of the battery. The countercell switches must likewise be located on this panel, as well as the two double-pole - double-throw fused switches required by the scheme of connections shown in Figure 3.

The logical arrangement of the above apparatus is on four panels, i.e. a generator panel, power feeder panel, street lighting panel and battery panel. However a certain standard catalogue single

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panel contains all the apparatus specified in the first two panels mentioned above, with the exception that there are four power feeder switches instead of three. This combination of two panels into one means a considerable saving, and will satisfactorily render the required service, and was therefore adopted. The attached photostat (Figure 4) shows the general layout of the switchboard, the specifications for which are as follows:

SWITCHBOARD SPECIFICATIONS.

Material of panels to be black marine finished slate.

Instruments to have dull black finish.

Panels to be mounted on substantial pipe framework.

Cardholders to be supplied where necessary.

SWITCHBOARD TO CONTROL:

1 - 250/125 V. 30 (A) Kw. D.C. 3-wire Generator.
2 - 250/125 V. 100 amp. D.C. 3-wire Feeder Circuits.
2 - 250/125 V. 200 amps. (max.) D.C. 3-wire Feeder Circuits.
4 - 250 V. 30 amps. (max.) D.C. 2-wire Feeder Circuits.
2 - 125 V. 50 amps. D.C. Battery Charging Circuits.

SWITCHBOARD TO CONSIST OF:

1 - D.C. Combination 3-wire Generator & 4-circuit Feeder Panel,
1 - D.C. 2-wire, 4-circuit Feeder Panel.
1 - D.C. Battery Charging Panel,
Bus Material.

ITEM #1:

1 - D.C. Combination 3-wire Generator and 4-circuit Feeder Panel.

Capacity: 250/125 V. 30 (A) Kw.

Size: 48 x 32 x 1-1/2" - Cat. 126552
16 x 32 x 1-1/2" - Cat. 126560

Mounted on 76" pipe supports.

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Mounted on 76" pipe supports.

Equipment

1 - D.P. Type C.G. 200 amp. circuit breaker with overload relays.
2 - Ground Detector Lamp Receptacles,
2 - 200 amp. R-6 Ammeters,
1 - 350 V. D-8 Voltmeter,
1 - Field rheostat support and extension shaft with coupling (no handwheel or dial plate included)
1 - 4 pt. Potential Receptacle with 4 pt. plug and holder,
1 - 6 pt. Ground detector Receptacle,
2 - T.P.S.T. 250 V. 100 amp. form D-12 service type lever Switches with 100 amp. NECS fuses,
2 - T.P.S.T. 250 V. 60 amp. form D-12 service type lever Switches, with NECS fuses mounted front of panel.

Connections between above lever switches and buses with clamps for attaching same to buses.

ITEM #2:

1 - D.C. 2-wire, 4-circuit Feeder Panel, Cat. 120630

Capacity: 250 V. 120 Amps. (max.)

Size: 48 x 20 x 1-1/2" - on 76" supports.

Equipment

4 - D.P.S.T. 250 V. 30 amp. form D-12 Lever Switch with one set of 30 amp. NECS fuses mounted on front of panel.

Connections between lever switches and buses with clamps for attaching same to buses.

ITEM #3:

1 - D.C. 2-circuit Battery Charging Panel.

Capacity: 125 V. 50 amps. per circuit.

Size: 48 x 24 x 1-1/2" - on 76" supports.

Equipment

1 - Single-pole, 250 V. 50 amp. form C.P. Underload Circuit Breaker,
2 - 60 amp. D-8 Ammeters with 60-0-60 amp. scale,
1 - 6 pt. Potential Receptacle,

Equipment

1 - D.P. Type C.S. 200 amp. circuit breaker with overload relays.
2 - Ground Detector Lamp Receptacles.
2 - 200 amp. R-6 Ammeters.
1 - 350 V. D-8 Voltmeter.
1 - Field rheostat support and extension shaft with coupling (no handwheel or dial plate included)
1 - 4 pt. Potential Receptacle with 4 pt. plug and holder.
1 - 6 pt. Ground Detector Receptacle.
2 - T.P.S.T. 250 V. 100 amp. Form D-12 service type lever Switches with 100 amp. NECS fuses.
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Connections between above lever switches and buses with clamps for attaching same to buses.

ITEM #2:

1 - D.C. 2-wire, 4-circuit Feeder Panel, Cat. 120630

Capacity: 250 V. 120 Amps. (max.)

Size: 48 x 20 x 1-1/2" - on 76" supports.

Equipment

4 - D.P.S.T. 250 V. 30 amp. Form D-12 Lever Switch with one set of 30 amp. NECS fuses mounted on front of panel.

Connections between lever switches and buses with clamps for attaching same to buses.

ITEM #3:

1 - D.C. 2-circuit Battery Charging Panel.

Capacity: 125 V. 50 amps. per circuit.

Size: 48 x 24 x 1-1/2" - on 76" supports.

Equipment

1 - Single-pole, 250 V. 50 amp. Form C.P. Underload Circuit Breaker.
2 - 60 amp. D-8 Ammeters with 60-0-60 amp. scale.
1 - 6 pt. Potential Receptacle.

2 - D.P.D.T. 250 V. 60 amp. form D-12 service type Lever Switches with one set of NECS fuses mounted on front of panel,
2 - 250 V. 50 amp. End Cell Switches, with 10 pts.

Connections between above Lever Switches and buses with clamps for attaching same.

ITEM #4:

Bus Material.

SECTION VI.

The Line Construction.

Poles:

The Northwestern Cedarmen's Association have drawn specifications covering poles, similar in their application to the Rules of the A. I. E. E., and it is good practice to specify poles to meet these specifictions. Twenty-five foot poles can be used in most placed in small villages, the exceptions being at railroad crossings, (where the state laws require forty foot poles) and where the trees would require trimming unless taller poles were used. When not more than two light cross arms are to be used, the tops of the poles may be scant six inches (i.e. from 5-1/2 to 6") in diameter inasmuch as these poles cost less than poles with full six inch tops, and serve the purpose just as well. In this part of the country, Northern White Cedar is standard, for it can be cut from the near-by forests in the Upper Peninsular. The butts of the poles should be creosoted, the cheapest method of giving the treatment consisting in applying the creosote with a plain brush 18" above and below the ground line, after the poles have been delivered to their destination. The desired results can be obtained in this manner at about 1/4 the cost of having the work done in the pole yards.

Cross-arms:

Cross-arms should be Washington fir-unpainted. These arms are extremely hard, and do not deteriorate when exposed to the weather. Pine cross-arms are cheaper but requires frequent painting as a protection against decay. The standard dimensions are 3-1/4 x 4-1/4". Two-pin arms

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are 3 feet long, four-pin arms 4 feet, and six-pin arms 6 feet. Figure 5 shows the details of the standard method of mounting cross-arms, and also gives the specifications of the necessary pole hardware used in securing them to the poles.

Pins and Insulators.

1-1/2" x 9" genuine locust pins represent standard practice in reference to pins. As to insulators deep groove double petticoat glass insulators have long been accepted as standard for electric lighting service.

Anchors.

The Mathews #502-R galvanized guy anchor is of the"screw type", which has the advantage over the"spread" type of avoiding the necessity of digging a hole. Its application is simple and quick, and therefore it is used to a large extent in guying poles which do not carry excessively heavy wires.

Street Lamp Suspension:-

To obtain the best illumination of the streets when tungsten lamps, spaced at distances of approximately 100 yards, are used, the lamps should be placed in the middle of the street. This method of suspension requires two poles to each lamp, but the better results obtained warrant the additional expense. The bracket arm suspension requires but one pole; but it is impossible to get the lamp out into the middle of the street, and therefore it is not to be recommended for use in street illumination, although it serves well in lighting country roads. The bottom of the lamp should never be lower than 20 feet from the ground, so that a man standing on a load of hay will clear it.

are 3 feet long, four-pin arms 4 feet, and six-pin arms 6 feet. Figure 5 shows the details of the standard method of mounting cross-arms, and also gives the specifications of the necessary pole hardware used in securing them to the poles.

Pins and Insulators.

1-1/2" x 9" genuine locust pins represent standard practice in reference to pins. As to insulators deep groove double petticoat glass insulators have long been accepted as standard for electric lighting service.

Anchors.

The Mathews #502-R galvanized guy anchor is of the"screw type", which has the advantage over the"spread" type of avoiding the necessity of digging a hole. Its application is simple and quick, and therefore it is used to a large extent in guying poles which do not carry excessively heavy wires.

Street Lamp Suspension:-

To obtain the best illumination of the streets when tungsten lamps, spaced at distances of approximately 100 yards, are used, the lamps should be placed in the middle of the street. This method of suspension requires two poles to each lamp, but the better results obtained warrant the additional expense. The bracket arm suspension requires but one pole; but it is impossible to get the lamp out into the middle of the street, and therefore it is not to be recommended for use in street illumination, although it serves well in lighting country roads. The bottom of the lamp should never be lower than 20 feet from the ground, so that a man standing on a load of hay will clear it.

The lamp can be lowered by means of a pulley when renewals are to be made. A pole lock should be used to lock the lamp in place, so as to prevent malicious tampering. 3/8" double galvanized seven strand steel cable should be used in supporting the street hood.

Lighting Protection:

Low voltage direct current plants do not encounter much trouble with lighting, and it is therefore necessary merely to place arresters in each circuit at the station with a few scattered throughout the system at the points where the feeders converge. The Garton-Daniels catalogue 50015 arrester, mounted in pole type wooden boxes, offers a servicable protective device which prooves very reliable. For station service the station type Garton-Daniels arrester #50014 should be specified. These arresters are shown in Figure 6.

Specifications:

The complete specifications for the line material, excepting the wire, is given in the following.

OVERHEAD DISTRIBUTION SYSTEM.

| MATERIAL: | Price F.O.B.Norwalk |
|---|---|
| 2 - 40'7" Northern White Cedar Poles | $ 22.40 |
| 2 - 35'6" Northern White Cedar Poles | 13.30 |
| 60 - 30'6" Northern White Cedar Poles | 240.00 |
| 50 - 25'6" Northern White Cedar Poles<br>All of the above poles to conform strictly with the specifications of the Northwestern Cedarmen's Association. | 105.00 |
| 90 - 5/8" x 10" Galv. machine bolts.<br>Each machine bolt to be complete with two 2-1/4 x 2-1/4 x 3/16" galv. sq. washers, 11/16" hole and one sq. nut. | 5.82 |
| 20 - 5/8" x 14" ditto | 1.54 |
| 500 - 24" x 1-7/32" double galv. cross arm braces. | 26.44 |

The lamp can be lowered by means of a pulley when renewals are to be made. A pole lock should be used to lock the lamp in place, so as to prevent malicious tampering. 3/8" double galvanized seven strand steel cable should be used in supporting the street hood.

Lightning Protection:

Low voltage direct current plants do not encounter much trouble with lightning, and it is therefore necessary merely to place arresters in each circuit at the station with a few scattered throughout the system at the points where the feeders converge. The Garton-Daniels catalogue 50015 arrester, mounted in pole type wooden boxes, offers a serviceable protective device which proves very reliable. For station service the station type Garton-Daniels arrester #50014 should be specified. These arresters are shown in Figure 6.

Specifications:

The complete specifications for the line material, excepting the wire, is given in the following.

OVERHEAD DISTRIBUTION SYSTEM.

| Material: | Price F.O.B. [illegible] |
|---|---|
| 2 - 40'7" Northern White Cedar Poles | $ 32.40 |
| 2 - 35'6" Northern White Cedar Poles | 13.30 |
| 50 - 30'6" Northern White Cedar Poles | 240.00 |
| 50 - 25'6" Northern White Cedar Poles | 105.00 |
| All of the above poles to conform strictly with the specifications of the Northwestern Cedarmen's Association. | |
| 10 - 5/8" x 10" Galv. machine bolts. Each machine bolt to be complete with two 2-1/4 x 2-1/4 x 3/16" galv. sq. washers, 11/16" hole and one sq. nut. | 5.84 |
| 20 - 5/8" x 14" ditto | 1.54 |
| [illegible] - 24" x 1-7/32" double galv. cross arm braces. | 25.44 |

| | | |
|---|---|---|
| 400 - | 3/8" x 4" galv. carriage bolts with nut and round washers for attaching cross arms braces to cross arms. | $ 3.64 |
| 200 - | 1/2 x 4" Dbl. galv. lag screws for attaching cross arm braces to poles. | 2.88 |
| 725 - | 1-1/2" x 9" genuine locust pins unpainted | 10.67 |
| 65 - | 3 ft. 2-pin 3-1/4 x 4-1/4 genuine Washington Fir cross arms unpainted, bored for 1-1/2" pins. 5/8" center bolts and 3/8" brace bolt holes. | 12.56 |
| 115 - | 4 pin 4 ft. ditto | 31.43 |
| 20 - | 6 pin 6 ft. ditto | 9.07 |
| 100 - | 1/2" x 14" galv.double arming bolts with four nuts and four 2-1/4 x 2-1/4 x 3/16" square washers with 9/16" holes. | 9.57 |
| 5000'- | 5/16" 7-strand double galv. guy wire | 45.00 |
| 300'- | 3/8" ditto. | 3.33 |
| 200'- | Standard 3-bolt rolled steel galv. guy clamps. | 21.30 |
| 40'- | #502-R Matthews galv. guy anchors. | 27.60 |
| 10'- | #603-R Matthews galv. guy anchors | 13.50 |
| 75 - | Galv. thimbles for 3/8" strand, | 1.55 |
| 150 - | 9/16" x 9" galv. pole steps. | 3.80 |
| 750 - | Deep groove, double petticoat glass insulators. | 23.60 |
| 14 - | Type D.F. station type Garton-Daniels lightning arresters, catalogue #50014. | 42.56 |
| 12 - | Wood box pole type Garton-Daniels lightning arresters, catalogue #50050. | 36.48 |
| 24 - | G. E. Center span suspension street hoods #103162. | 68.40 |
| 24 - | #32 Ajax swivel pulleys or equal. | 11.04 |

## SECTION VII.

### The Cost of the Plant.

Following is a tabulation of the cost of the plant excluding the cost of erection.

| | |
|---|---|
| 1 -30 K.W. 1300 R.P.M. 125/250 Volt,3-wire generator with pulley, base, rheostat and balancer coils. | $450.00 |
| 1 -3 Panel Switchboard. | 453.00 |
| 1- E-7 Battery in E-9 jars. | 1,030.00 |
| 1- 50 H.P. oil engine with tank. | 1,996.00 |
| Line material and wire. | 2,000.00 |
| | $5,929.00 |
| Erection estimated at - | 700.00 |
| Total cost of Installation: | $6,629.00 |

This cost is just with the limit of $7,000.00 which was available to be spent in the erection of the plant.

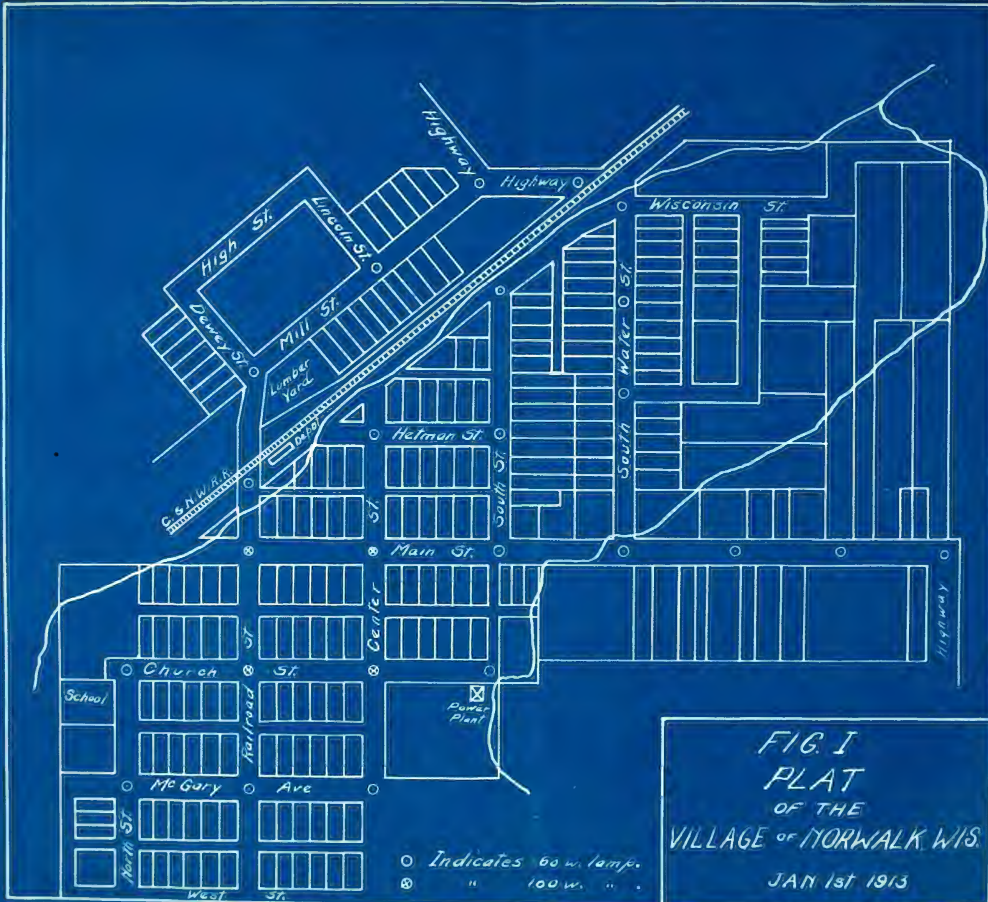



FIG. I
PLAT
OF THE
VILLAGE OF NORWALK WIS.
JAN 1st 1913

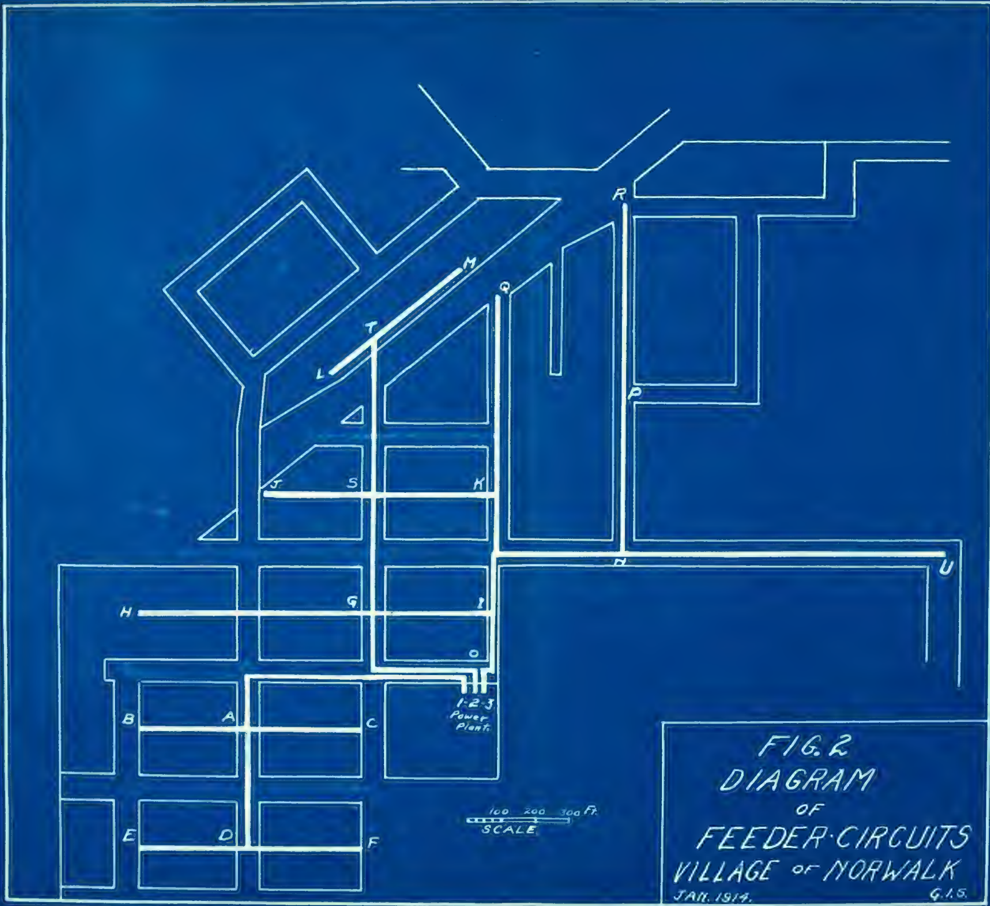
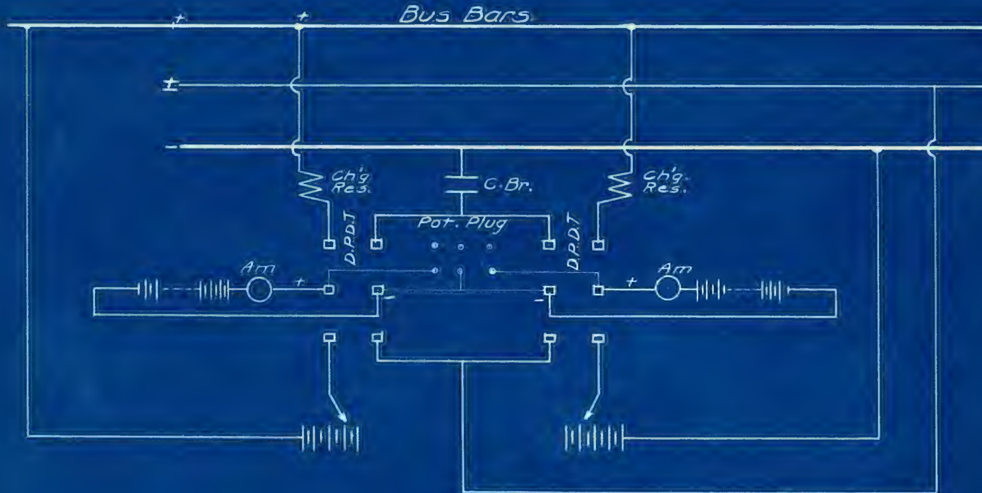



FIG. 2
DIAGRAM
OF
FEEDER·CIRCUITS
VILLAGE OF NORWALK
JAN. 1914. G.I.S.




VILLAGE OF NORWALK-WIS.
BATTERY PANEL

FIG. III

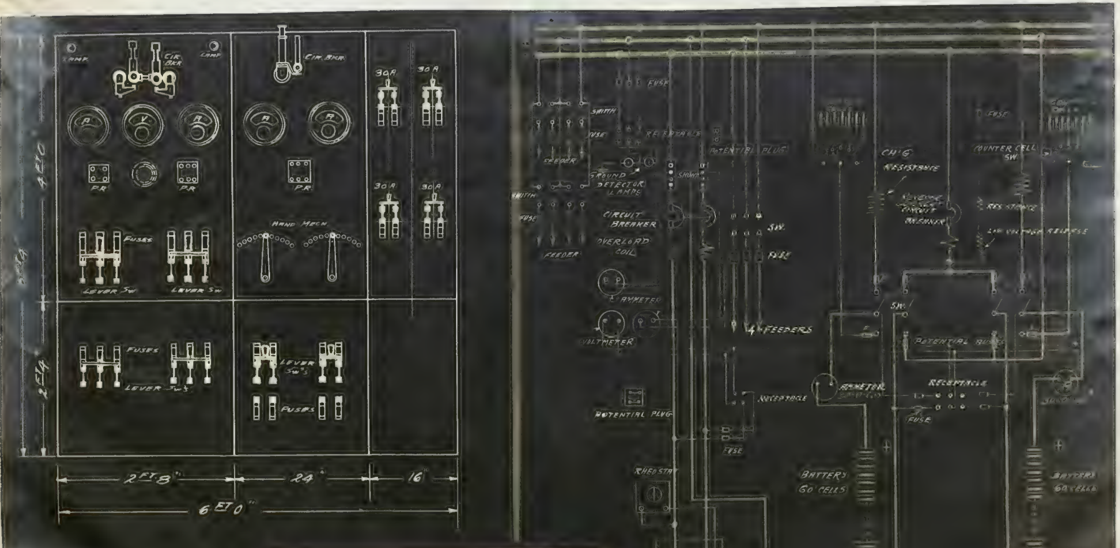
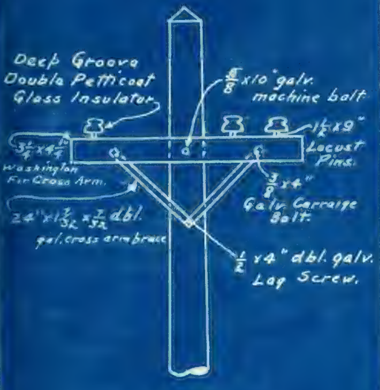
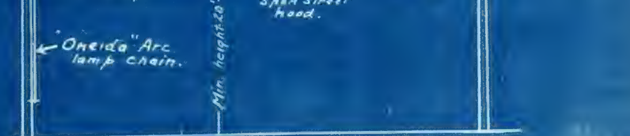



FIG. IV
Switchboard Layout.
Village of Norwalk




CROSS ARM DETAIL.


POLE BRACING DETAIL.




STREET LAMP SUSPENSION.

FIG. V.

3-18-34 — G.H.S.

Arrester has combined with its unusually free discharge path a means for unfailingly interrupting this flow to ground, so rendering accidental grounds and short circuits on the system, so common with some types of Lightning Arresters, practically an impossibility.

For alternating current electric railway systems the CE-2 and F-2 Type Arresters are perfectly adapted—the conditions being similar to those existing on grounded neutral circuits. Where but one trolley wire is used, these Arresters should be installed in the same manner as on direct current systems. If two trolleys are employed, the rail forming the other side of the circuit, Arresters should be placed on each of the exposed wires, the same ground being used and this wire connected with the rail. Such a connection with the rail insuring protection between the sides of the circuit, against excessive voltages, due to switching, etc.

# Direct Current Lightning Arresters

### For Voltages up to 2,400
### Types DF, ~~EG, EH, EI, EJ and EK~~

The line of direct current Garton-Daniels Lightning Arresters represents the outcome of constant development work carried on by this Company. It is a complete line, comprising Arresters for direct current lighting and power circuits, direct current arc circuits, and for electric railway circuits operating at voltages up to 2400.

These arresters are constructed and operate along lines which are practically identical. The construction and operation of one only will be here considered—the type EG, for railway service of from 350 to 750 volts—and brief references made to the other various types.

### Construction and Operation

Refer to Diagram No. 3 on following page showing constructional and operative details of this type EG Arrester.

Line connection is at the top of Arrester, ground connection at the bottom. The lightning discharge takes the path as shown by the round dots, having a practically straight path from line to ground. This path is practically non-inductive; and is composed entirely of massive conducting bodies. Note in this connection that band E at the lower end of the resistance rod is electrically connected with

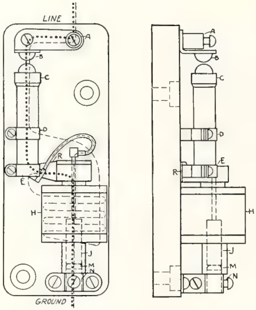



Diagram No. 3

the upper spool bracket by means of a heavy copper strip, R, on the base. By the use of this copper connection, the lightning discharge does not even flow through the flexible cable connecting the upper end of the movable plunger with band E; cutting out the inductance of this flexible cable has appreciably increased the sensitiveness of the Arrester.

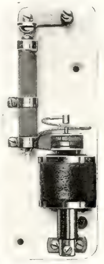
On grounded electric railway circuits, after a lightning discharge has broken down and arced over the air gap, a path is offered through the Arrester for normal or dynamic current from line to ground, which must be instantly cut off by the Arrester. The path for this normal or line current is as shown by the dashed line; it, the same as the lightning discharge, crosses upper air gap B, thence flowing through section CD of the resistance rod. Reaching point D it is shunted into the magnet coil H,—for reasons see page 39, pertaining to operation of the type CE Arrester—flows through this winding to point E, thence through flexible lead, iron plunger J (which rests on a carbon button M connected to ground binding post N), thence to ground.

This flow of line current through coil H, energizes the iron plunger J, which rises upward in the coil, opening the circuit between the lower end of the plunger and the carbon button M. This cuts off the flow of line current to ground, the arc at gap B dies out, the coil loses its energy and the plunger returns by gravity to its normal position. The Arrester is instantly ready for another discharge.

Note that the arc is not broken at the air gap, but inside a fibre tube between iron and carbon. This method of cutting off the flow of line current to ground at a point other than the air gap itself, simply allows the arc to die out at the gap; the gap electrodes are not blistered or burnt; the gap is not gradually lengthened due to small particles of the metal being burned away. For this reason it is possible to use the small air gap that has given the Garton-Daniels

Arrester such a high record for efficiency and service. In this type EG Arrester, the air gap distance between line and ground is 1/40 (.025) inch.

To limit the flow of normal current that can follow the discharge to ground, we employ the upper section of the resistance rod, there being approximately 60 ohms between discharge point C and clamp D. This keeps the current down to a value that is broken readily by the circuit breaker, and is not enough resistance to impede the passage of the discharge.



Type E G Lightning Arrester for Station Use

Important constructional details of Garton-Daniels Direct Current Lightning Arresters are ample surface distances on the base between parts of different potentials; if these ample distances were not allowed, when the base became dusty and wet from condensation, the line voltage would frequently arc over between metal parts and result in the destruction of the Arrester. Resistance rods are of low resistance and of great efficiency in conducting high frequency static and lightning. This resistance is permanent—that is, is unaffected by the passage of static discharges as some rods are. This means that the efficiency of the Arrester is not decreased after continued service due to an increase in rod resistance.

The resistance rod is supported by the Brackets D and E, the upper end of the rod being free from contact with the base. In this way a distance of 2½ inches on the surface of the base is secured between the support for the upper discharge point B and the bracket D. This feature is new in lightning arrester design, and entirely removes one of the weak points found in former types. The lower discharge point C is cemented to the rod by means of a special metallic cement that has been thoroughly tried out and found permanent.

The design of Garton-Daniels Lightning Arresters throughout assures Arresters of very high efficiency. Furthermore, service tests demonstrate that a long life is assured, and the best of results throughout a period of years may be expected.